

Vocal Emotion Perception: A Comparison of Singers and Instrumentalists, Amateurs and Professionals --Manuscript Draft--

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Abstract:	<p>Musicians outperform non-musicians in vocal emotion recognition, presumably due to differences in auditory sensitivity. However, the current literature is inconclusive regarding differential effects of specific types of musical activity. Given the tight link between expression and perception in vocal emotional communication, we assessed possible effects of whether music is expressed vocally or not, and whether music is performed on an amateur or professional level. Importantly, however, we predicted that vocal emotion recognition would be unaffected by the type and amount of musical activity because current evidence argues against a causal role of formal musical education. We compared emotion recognition performance of singers (N= 45) vs. instrumentalists (N = 43) and professional musicians (N = 40) vs. amateurs (N = 88) vs. non-musicians (N = 38). Using both frequentist and Bayesian inference, we found the predicted nulleffects for singers vs. instrumentalists, and professionals vs. amateurs. Evidence for an advantage in amateurs vs. non-musicians was inconclusive. Across groups, we replicated the consistent link between vocal emotion perception and auditory sensitivity. Overall, the current work aligns with the perspective that musicians' advantage in recognizing vocal emotions is rooted in auditory sensitivity, rather than specific types of musical activities or formal training.</p>
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Dear Editors of *iScience*,

attached please find a new manuscript entitled “Vocal Emotion Perception: A Comparison of Singers and Instrumentalists, Amateurs and Professionals” for possible publication as a research article in *iScience*. This work covers an interdisciplinary topic in social and health science and therefore fits the scope of this journal. Our findings close an important gap concerning the role of musicality for vocal emotional processing and will be of relevance for emotion researchers, experts on voice and speech studies, as well as psychologists and musicians in applied fields.

Musicians outperform non-musicians in vocal emotion recognition. However, the current literature is inconclusive regarding differential effects of specific types of musical activity. To address this gap, we compared emotion recognition performance of singers (N= 45) vs. instrumentalists (N=43) and professional musicians (N = 40) vs. amateurs (N = 88) vs. non-musicians (N = 38). Importantly, we predicted that vocal emotion recognition would be unaffected by the type or amount of musical activity. Using both frequentist and Bayesian inference, we found the predicted null effects for singers vs. instrumentalists, and for professionals vs. amateurs. Across groups, we replicated the link between vocal emotion perception and auditory sensitivity, suggesting that musicians’ advantage in recognizing vocal emotions is rooted in auditory sensitivity, rather than in the specific type or amount of musical activities.

We want to highlight two important aspects of this work: First, we specifically predicted and preregistered a null-effect of musical activity. Therefore, we used Bayesian inference alongside established frequentist approaches in our statistical analyses. Second, we recruited an original sample of 45 singers and 43 instrumentalists, which were all amateur musicians. To compare them to professionals and non-musicians, we used a previously recruited sample (Nussbaum et al. 2024, 10.1111/bjop.12684). This is made transparent throughout in the manuscript.

To the best of our knowledge, this is the first well-powered and preregistered study on vocal emotion capacities of different musical subgroups. It has not been published previously, is not under consideration for publication elsewhere, and is approved by all authors. The preregistration, preprocessed data, analysis scripts, and supplemental materials are available at OSF (<https://osf.io/ascqx/>). We expect this manuscript to be of great interest to the wide readership of *iScience*.

Yours sincerely,

Christine Nussbaum, Jessica Dethloff, Annett Schirmer and Stefan R. Schweinberger



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Vocal Emotion Perception: A Comparison of Singers and Instrumentalists, Amateurs and Professionals

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Abstract

Musicians outperform non-musicians in vocal emotion recognition, presumably due to differences in auditory sensitivity. However, the current literature is inconclusive regarding differential effects of specific types of musical activity. Given the tight link between expression and perception in vocal emotional communication, we assessed possible effects of whether music is expressed vocally or not, and whether music is performed on an amateur or professional level. Importantly, however, we predicted that vocal emotion recognition would be *unaffected* by the type and amount of musical activity because current evidence argues against a causal role of formal musical education. We compared emotion recognition performance of singers (N= 45) vs. instrumentalists (N = 43) and professional musicians (N = 40) vs. amateurs (N = 88) vs. non-musicians (N = 38). Using both frequentist and Bayesian inference, we found the predicted nulleffects for singers vs. instrumentalists, and professionals vs. amateurs. Evidence for an advantage in amateurs vs. non-musicians was inconclusive. Across groups, we replicated the consistent link between vocal emotion perception and auditory sensitivity. Overall, the current work aligns with the perspective that musicians' advantage in recognizing vocal emotions is rooted in auditory sensitivity, rather than specific types of musical activities or formal training.

Keywords: vocal emotion perception, singers, instrumentalists, amateurs, musicality

Public significance statement

- Musicians outperform non-musicians in vocal emotion perception, but it is currently unclear whether this effect is modulated by the specific type of musical activity
- To address this gap, we compared vocal emotion perception in singers vs. instrumentalists and in amateurs vs. professional musicians
- In line with our predictions, we found no difference between either of these subgroups, suggesting that vocal emotion perception is unaffected by the type and amount of musical activity
- Across groups, we replicated the link between natural auditory sensitivity and vocal emotion perception

1 Introduction: associations between musicality and vocal emotion perception

The human voice is a prime carrier of emotional information. Therefore, adequate perception of vocal emotions is important for everyday social interaction (Laukka et al., 2016; Schirmer et al., 2025). On average, humans can infer emotions from voices well above chance (Banse & Scherer, 1996; Juslin & Laukka, 2003; Scherer, 2018), but this capacity is subject to great individual variability and seems to be linked to differences in *musicality* (Lima & Castro, 2011). It has been shown repeatedly that musicians outperform non-musicians in vocal emotion recognition, although the overall effect size can be considered small to moderate (M. Martins et al., 2021; Nussbaum & Schweinberger, 2021; Schellenberg & Lima, 2024). Several works sought to unravel the potential mechanisms underlying this advantage. They collectively point to the role of *auditory sensitivity*. Compared to non-musicians, musicians have more fine-grained basic auditory skills, such as pitch and rhythm perception, musical memory, or signal-in-noise discrimination (Baldé et al., 2025; Kraus & Chandrasekaran, 2010), which aids vocal emotion recognition. Importantly, this does not seem to depend directly on formal musical training: The association between auditory perception and vocal emotion recognition was observed even in the absence of any formal musical training (Correia et al., 2022; Lima et al., 2016; Nussbaum et al., 2024; Thompson et al., 2012; Vigl et al., 2024). Further, Correia et al. (2022) found that the link between musical training and vocal emotion perception was fully mediated by auditory perception skills. The presumably strongest evidence is provided by a recent randomized-controlled study in school children, which found no causal effects of musical training on vocal emotion perception performance (Neves et al., 2025). Thus, there is consensus in the literature that the observed performance difference of musicians and non-musicians is due to variations in natural auditory sensitivity rather than the result of formal musical education (Schellenberg & Lima, 2024).

In a previous study, we investigated how musicians' auditory skills promote vocal emotion perception in more detail, by focusing on different auditory cues that transport emotional meaning (Nussbaum et al., 2024). We employed parameter-specific voice morphing to create vocal stimuli that expressed emotion only through fundamental frequency contour (F0), timbre or both. F0 is linked to dynamic pitch variation (also referred to as voice melody), whereas timbre is linked to perceived voice quality (i.e. whether it sounds harsh or gentle). Professional musicians outperformed a group of non-musicians when emotions were expressed by F0 and both cues, but not timbre alone. Thus, musicians seem to be specifically proficient at exploiting melodic patterns to infer vocal emotions.

While the available literature paints a fairly consistent picture regarding the link between musicality and vocal emotion perception, a key limitation inherent in most studies targeting group differences is that they treat musicians as one uniform group, which is, in fact, highly heterogeneous. On the one hand, there are quantitative differences regarding levels of expertise. On the other hand, there are qualitative differences between musicians linked to a variety of styles, genres, and forms of expression, within the scope of the Western music system and beyond. A particularly interesting distinction in the context of vocal emotions is the one between **singers and instrumentalists**. Singing is arguably the form of musical expression that is most closely related to vocal emotions (Akkermans et al., 2019; Mithen et al., 2006). Another interesting debate revolves around differences between **professional musicians and amateurs** (Vincenzi et al., 2022). Therefore, the present study targeted these subgroups to explore their capacity for vocal emotion perception. In what follows, we review current insights and outstanding research gaps, cumulating in the rationale for the present study.

1.1 Singers vs. instrumentalists

Singing and playing an instrument are both fundamental forms of musical expression in humans, but they require very different motor skills and, typically, different amounts of formal musical training (Fisher et al., 2020; Krishnan et al., 2018). Crucially, singers use their voice for musical expression. This is reflected in vocal performance differences, as for example, singers outperform instrumentalists in foreign accent imitation (Christiner & Reiterer, 2015). But does this hold for the perception of vocal cues as well? Neuroscientific research revealed substantial overlap between the neural circuits involved in the expression and perception of vocal information (Frühholz & Schweinberger, 2021), but this does not necessarily imply that individuals with supreme expertise in vocal expression would have benefits in perception as well (Nikjeh et al., 2009). In fact, I. Martins et al. (2022) found no differences in electrophysiological responses to emotional voices between singers and instrumentalists, suggesting similar profiles of auditory processing. Apart from this study, relevant evidence regarding vocal emotion perception is sparse and inconclusive. Several studies observed correlations between vocal emotion perception and singing abilities, either self-rated or objectively measured (Correia et al., 2022; Greenspon & Montanaro, 2023; Nussbaum et al., 2024), but all samples comprised both singers and instrumentalists. Intriguingly, a music-intervention study reported that singing may even interfere with vocal emotional processing, while instrument lessons had a positive effect (Thompson et al., 2004). However, the validity of this finding is limited by an extensive drop-out of participants and a small sample size (Schellenberg & Lima, 2024). Overall, the few data that are available do not provide clearcut evidence for a specific benefit in vocal emotion recognition by singing over playing an instrument. We therefore pursued the null hypothesis of there being no such differences. In view of the limitations of previous studies, we recruited a well-powered sample of instrumentalists and singers.

1.2 Amateurs vs. professional musicians

Most musicians start with their formal training in childhood, but when they enter adulthood, they pick different paths: some convert their musical activity into a profession, whereas others pursue another career and keep music as a hobby. Interestingly, these groups seem to display several differences with regard to neurocognitive functioning. While amateurs, unsurprisingly, score lower on musical abilities, they show better cognitive abilities in terms of abstract reasoning than professional musicians (Vincenzi et al., 2022). Amateurs may gain more positive outcomes from their musical activity. Perhaps because it takes up less time in their lives, it is enriching, while at the same time minimizing negative consequences related to, for example, exposure to high amplitude sounds and performance pressure. This also seems to be reflected in general health, which was found to be better in amateurs than professionals (Bonde et al., 2018; Hake et al., 2024; Loveday et al., 2023; Maghiar et al., 2023; Rogenmoser et al., 2018). On a different note, one recent study reported that professionals when compared with amateurs were more likely to experience a state of flow during their musical activity, which is usually considered very enjoyable (Rakei & Bhattacharya, 2024). However, to the best of our knowledge, there have been no comparisons between amateurs and professionals with regard to vocal emotion perception. This gap is addressed with the present study.

1.3 Rationale of the present study

This study focuses on the comparison between singers and instrumentalists as well as professionals and amateurs, and thus zooms into possible similarities or differences between specific subgroups while using an almost identical protocol as Nussbaum et al. (2024). We report our findings in three parts. For Part I, we recruited an original sample of amateur instrumentalists and singers and compared their vocal emotion recognition, their musical perception performance and self-rated musicality. In Part II, we focused on the correlations

between these measures, in order to replicate the link between auditory sensitivity and vocal emotion recognition reported by previous studies. Finally, because all our newly recruited singers and instrumentalists were amateurs, the present study offered the opportunity to compare findings with our previously recruited groups of professional musicians and non-musicians (Nussbaum et al., 2024), which we report in Part III.

As mentioned above, we predicted that singers and instrumentalists as well as professionals and amateurs perform equally well in our vocal emotion recognition task, both for emotions expressed by all available vocal cues, as well as emotions expressed by either F0 or timbre cues. We derived these predictions from previous research suggesting that the neural processing of vocal emotions is comparable in singers and instrumentalists (I. Martins et al., 2022). Moreover, we relied on behavioral evidence that the link between musicality and vocal emotion perception is not driven by formal training, but rather by natural differences in auditory sensitivity (Correia et al., 2022; Neves et al., 2025). This study and its hypotheses have been preregistered (<https://doi.org/10.17605/OSF.IO/76PV5>).

2 Part I: Comparison of non-professional singers and instrumentalists

2.1 Hypotheses

Regarding the comparison between singers and instrumentalists, we formulated the following hypotheses:

H1: We expect *no* difference between singers and instrumentalists in overall vocal emotion recognition performance.

H2: We expect *no* difference between singers and instrumentalists in vocal emotion recognition performance based on timbre and F0 cues only.

2.2 Method

Note that this is a follow-up to the study reported in Nussbaum et al. (2024). Thus, the stimulus material and the design are almost identical, but we recruited a new sample.

2.2.1 Participants

According to our preregistered plan, we aimed at a sample size of 40 singers (20 male, 20 female) and 40 instrumentalists (20 male, 20 female), because in our previous study, this sample size allowed us to reveal medium-sized group effects ($d = 0.56 - 0.81$) when we compared professional musicians and non-musicians.

Data were collected in a pseudonymized format from June 2023 to January 2024. All participants were aged between 18 and 54 years and fluent German speakers. Participants provided informed consent before completing the experiment and received compensation in the form of 12.50 € or course credit upon completion. The experiment was in line with the ethical guidelines by the American Psychological Association (APA) and approved by the local ethics committee of the Friedrich Schiller University Jena (Reg.-Nr. FSV 19/045).

In total, we collected data from 94 amateur musicians that were divided into singers and instrumentalists. Recruitment criteria specified that participants had to be non-professional musicians (i.e., they held no music-related academic degree or worked professionally as a musician). Singers were required to be currently active in a choir or another singing group but should not play an instrument actively and regularly (i.e., they must not currently be instrumentalists in an orchestra or a band). Instrumentalists, conversely, were required to be currently active in an orchestra or a band, but they should not engage in singing activities actively and regularly (i.e., they must not currently be in a choir or another singing group).

Singers

We recorded data from 48 singers, of which three were excluded ($N = 2$ had $> 5\%$ trials of omission, $N = 1$ had technical issues during stimulus playback). Thus, data from 45 singers

were analyzed (22 female, 22 male, 1 diverse, aged 18 to 53 years [$M = 27.02$, $SD = 8.2$]). Mean onset age of musical training was 8 years ($SD = 3.08$, 5 - 20 years). Mean duration of musical training was 10 years ($SD = 6.59$, 0 – 25 years). Five participants reported that they never had any formal musical training. Two participants reported that they had occasional tinnitus, but without any subjective impairments in daily life.

Instrumentalists

Data from 46 instrumentalists were collected, of which three were excluded. One had technical issues during stimulus playback, one was also active in a choir, one held a master's degree in music science and was therefore regrouped with the professional musicians (see Part III). Thus, data from 43 instrumentalists entered analysis (24 female, 18 male, 1 diverse, aged 18 to 54 years [$M = 28.51$, $SD = 10.64$]). Mean onset age of musical training was 7 years ($SD = 2.27$, 4 - 14 years). Mean duration of musical training was 14 years ($SD = 10.00$, 0 – 44 years). Four participants reported that they never had any formal musical training, thus were autodidacts. For more details, see Table S1 on OSF.

2.2.2 Stimulus material

As stimulus material, we used parameter-specific voice morphs that express emotional information either through the fundamental frequency contour only (F0), through timbre only (Tbr) or through a combination of both (Full).

For voice morphing, we selected original audio recordings from a database of vocal actor portrayals, comprised of pseudowords (/molen/, /loman/, /belam/) uttered by eight speakers (four male, four female) with expressions of happiness, pleasure, fear, and sadness. To synthesize the parameter-specific emotional voice morphs, we created morphing trajectories between each emotion and an emotional average of the same speaker and pseudoword, using the Tandem-STRAIGHT software (Kawahara et al., 2013; Kawahara et al., 2008). The averages had been created previously by blending all emotions together and were thus assumed to be uninformative and unbiased with respect to the four emotions of

interest. After substantial preprocessing (e.g. manual mapping of time- and frequency anchors in each stimulus), Tandem-STRAIGHT enables voice morphing via weighted interpolation of five independent parameters: (1) F0-contour, (2) timing, (3) spectrum-level, (4) aperiodicity, and (5) spectral frequency; the latter three are summarized as timbre.

We created three types of morphed stimuli (see **Figure 1**). **Full-Morphs** were stimuli with all parameters taken from the emotional version (corresponding to 100% from the emotion and 0% from average), except for the timing parameter, which was taken from the average (corresponding to 0% emotion and 100% average). **F0-Morphs** were stimuli with the F0-contour taken from the emotion, but timbre and timing were taken from the average.

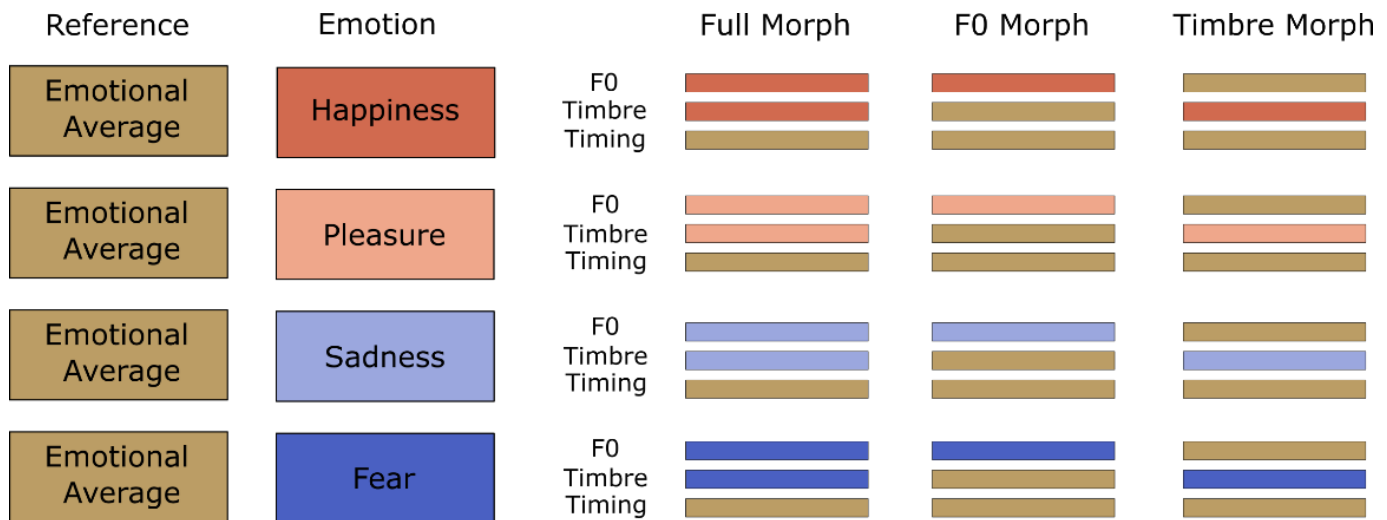
Timbre-Morphs were stimuli with all timbre parameters taken from the emotion, but F0 and timing from the average. Note that the timing was kept constant in all conditions to allow a pure comparison of F0 vs. timbre. Furthermore, we kept all average stimuli as a further ambiguous reference category. In total, this resulted in 8 (speakers) x 3 (pseudowords) x 4 (emotions) x 3 (morphing conditions) + 24 average (8 speakers x 3 pseudowords) = 312 stimuli (duration $M = 780$ ms, range 620 to 967 ms, $SD = 98$ ms). Using PRAAT (Boersma, 2018), we normalized all stimuli to a root-mean-square of 70 dB SPL.

For a more detailed description of the stimulus creation, see Nussbaum et al. (2024) and Kawahara and Skuk (2018). For a summary of acoustic characteristics, see Tables S3 and S4 on OSF.

Figure 1

Morphing matrix for stimuli with averaged voices as reference

Vocal Emotion Perception – Singers vs. Instrumentalists



Note. Figure reprinted from Nussbaum et al. (2024), Fig 2, page 6

2.2.3 Design

Data were collected online via PsyToolkit (Stoet, 2010, 2017), but after completion of the study all participants met with the experimenter for a short personal debriefing. This was done to increase commitment and conscientiousness for the experiment.

Participants were required to ensure a quiet environment for the duration of the study and use a computer with a physical keyboard and headphones. As browser, we recommended Google Chrome, and excluded Safari for technical reasons. Prior to the listening tasks, participants could adjust their sound settings to a comfortable sound pressure level.

First, participants entered demographic information, including age, sex, native language, profession, and potential hearing impairments such as tinnitus. They then completed an emotion classification experiment, a test on music perception and several questionnaires on musicality, personality and socioeconomic background. Mean duration of the whole online study was about 75 minutes.

Emotion classification experiment

In the experiment, participants classified vocal emotions as happiness, pleasure, fear, or sadness. Each trial started with a green fixation cross presented for 500 ms. Then the sound was played while a loudspeaker symbol was shown on the screen. Subsequently, a response screen showed the emotion labels and participants could enter their response within a 5000 ms time window starting from voice offset. Responses were entered with the left and right index and middle fingers, with random mapping of response keys to emotion categories for each participant, out of four possible key mappings (see Tables S5 and S6 on OSF). In case of a response omission, the final trial slide (500 ms) prompted participants to respond faster; otherwise, the screen turned black. Then the next trial started.

The 312 stimuli were presented in randomized order in six blocks of 52 trials each, with self-paced breaks in between. Beforehand, participants completed eight practice trials with different stimuli. The experiment was about 25 minutes long. Unfortunately, due to a software error, randomization was sampled with replacements, so that some stimuli were drawn repeatedly and others were omitted. This was in contrast to our previous study, where randomization was sampled without replacement so that each stimulus was drawn exactly once.

Profile of Music Perception Skills (PROMS)

To measure music perception skills, we used a modular version of the Profile of Music Perception Skills (Law & Zentner, 2012; Zentner & Strauss, 2017), comprised of the four subtests „Melody“, „Pitch“, „Timbre“, and „Rhythm“. Participants completed 18 items per subtest, always preceded by one practice trial. Each trial, participants heard a reference stimulus twice followed by a target stimulus. Then, they indicated whether reference and target were the same or different via a 5-point Likert scale with the labels “definitely same”, “maybe same”, “don’t know”, “maybe different”, and “definitely different”. The duration of the PROMS was about 20 minutes.

Questionnaires

After the PROMS, participants completed several questionnaires: the German Version of the Autism Quotient Questionnaire, AQ, (Baron-Cohen et al., 2001; Freitag et al., 2007), a 30-item Personality Inventory measuring the Big-Five domains (Rammstedt et al., 2018), the Goldsmiths Musical Sophistication Index, Gold-MSI, (Müllensiefen et al., 2014) to assess the participants' degree of self-reported musical skills, additional questions concerning music experience and musical engagement, their socioeconomic background, and the 20-item version of the Positive-Affect-Negative-Affect-Scale, PANAS (Breyer & Bluemke, 2016; Watson et al., 1988).

2.2.4 Data analysis

In line with our preregistered plan, we collapsed data across speakers and pseudowords for analysis. Further, data on emotional averages were excluded because they were not relevant for our hypotheses. Response omissions (~1 %) were treated as errors and participants with more than 5% of such omissions excluded from data analysis. Analyses of Variance (ANOVAs) and correlational analyses were performed using R Version 4.5.0 (R Core Team, 2025). Post-hoc tests were Benjamini-Hochberg corrected where appropriate (Benjamini & Hochberg, 1995).

We complemented these classical frequentist analyses with a Bayesian approach, which – in contrast to null hypothesis significance testing - allows a quantification of evidence for null findings (Rosenfeld & Olson, 2021). These analyses were conducted in JASP Version 0.19.3 (JASP Team, 2025) using default priors. We report the Bayes factor (BF_{10}) as an indicator for the likelihood of the null and alternative hypothesis given the observed data. $BF_{10} > 1$ indicate larger evidence for the alternative hypothesis, $BF_{10} < 1$ indicate larger evidence for the null hypothesis. For example, a $BF_{10} = 3$ means that the alternative hypothesis is three times more likely than the null hypothesis, whereas the

reciprocal $BF_{10} = .33$ means that the null hypothesis is three times more likely than the alternative. Following the guidelines by Jarosz and Wiley (2014), we consider values of $BF_{10} = 1-3$ (.1-.33) as anecdotal, $BF_{10} = 3-10$ (.33-.10) as moderate, $BF_{10} = 10-30$ (.10-.03) as strong, $BF_{10} = 30-100$ (.03-.01) as very strong and $BF_{10} > 100$ (< .01) as decisive evidence for the alternative hypothesis and the reciprocal values in parentheses as respective evidence for the null hypothesis.

In alignment with the approach by Nussbaum et al. (2024), we recoded responses in the PROMS from 0 to 1 in 0.25 steps starting with the “definitely” correct option down to the “definitely” incorrect option (thus, “don’t know” was always coded with 0.5) and subtracted 0.5 from the final measure. Thus, a positive score indicates that participants were more correct/confident, whereas a negative score indicates more incorrect/uncertain ratings. For statistical analyses, we used the averaged performance across trials for each subtest.

2.3 Transparency and openness

We specified how we determined our sample size, all data exclusions, all manipulations, and all measures in the associated preregistration (<https://doi.org/10.17605/OSF.IO/76PV5>). Preprocessed data, analysis scripts and supplemental materials can be found in the associated OSF repository (<https://osf.io/ascqx/>).

2.4 Results

2.4.1 Demography, musicality, and personality of participants

Singers and instrumentalists did not differ significantly in the socioeconomic status assessed via educational level, $X^2(2, N = 88) = 1.06, p = .588$; highest academic degree, $X^2(7, N = 88) = 9.06, p = .249$, and household income, $X^2(4, N = 88) = 5.23, p = .264$ (for more details see Table S2 on OSF). Further, the groups did not differ in age or positive and negative affect (assessed with the PANAS) and were comparable regarding Big Five personality traits and autistic traits. In the Gold-MSI, singers and instrumentalists scored comparatively on the

general musicality score, but there were differences on two subfactors: instrumentalists scored higher on the subfactor Formal Education, while singers scored higher on Singing. In the PROMS, both groups performed comparably in all four subtests. Participant characteristics assessed via self-report and music performance in the PROMS are summarized in **Table 1**.

Table 1

Characteristics of participants - Demography, personality, and musicality

	<u>Singers</u>	<u>Instrumentalists</u>					
	M (SD)	M (SD)	t	df ^a	p	Cohen's d	
Age	27.02 (8.2)	28.51 (10.6)	-0.73	78.93	.465	-0.17 [-0.61, 0.28]	
<i>PANAS</i>							
positive Affect	3.00 (0.68)	3.11 (0.57)	-0.77	84.78	.446	-0.17 [-0.59, 0.26]	
negative Affect	1.53 (0.47)	1.40 (0.35)	1.49	80.61	.141	0.33 [-0.11, 0.77]	
<i>Big Five</i>							
Openness	4.04 (0.55)	3.99 (0.51)	0.46	85.96	.647	0.10 [-0.32, 0.52]	
Conscientiousness	3.47 (0.69)	3.76 (0.70)	-1.91	85.62	.060	-0.41 [-0.84, 0.02]	
Extraversion	3.21 (0.70)	3.00 (0.73)	1.44	85.3	.155	0.31 [-0.12, 0.74]	
Agreeableness	3.81 (0.57)	4.01 (0.60)	-1.61	85.29	.112	-0.35 [-0.77, 0.08]	
Neuroticism	2.74 (0.77)	2.61 (0.78)	0.80	85.75	.426	0.17 [-0.25, 0.60]	
<i>AQ</i>							
Total	18.2 (6.15)	19.28 (8.55)	-0.68	76.04	.500	-0.16 [-0.60, 0.30]	
Attention to Detail	5.4 (2.33)	5.63 (2.53)	-0.44	84.64	.662	-0.10 [-0.52, 0.33]	
Social	12.8 (5.37)	13.65 (7.53)	-0.61	75.65	.545	-0.14 [-0.59, 0.31]	
Social Skills	2.4 (1.94)	3.09 (2.95)	-1.30	72.01	.200	-0.31 [-0.77, 0.16]	
Communication	2.53 (1.94)	2.44 (2.31)	0.20	82.02	.842	0.04 [-0.39, 0.48]	
Imagination	2.51 (1.75)	2.81 (1.88)	-0.78	84.86	.437	-0.17 [-0.60, 0.26]	
Attention Switching	5.36 (1.91)	5.30 (2.23)	0.12	82.69	.905	0.03 [-0.40, 0.46]	
<i>Gold-MSI</i>							
General ME	4.78 (0.85)	4.75 (0.80)	0.17	85.99	.866	0.04 [-0.39, 0.46]	
Active Engagement	3.83 (0.82)	4.21 (1.13)	-1.79	76.79	.078	-0.41 [-0.86, 0.05]	
Formal Education	4.39 (1.14)	4.95 (0.62)	-2.85	68.31	.006	-0.69 [-1.18, -0.20]	**
Emotion	5.50 (0.81)	5.60 (0.76)	-0.60	85.99	.549	-0.13 [-0.55, 0.29]	
Singing	4.98 (0.97)	4.19 (1.27)	3.25	78.56	.002	0.73 [0.27, 1.19]	**
Perception	5.73 (0.82)	5.77 (1.03)	-0.22	80.11	.825	-0.05 [-0.49, 0.39]	

<i>PROMS</i>						
Pitch	0.23 (0.08)	0.24 (0.06)	-0.30	82.92	.766	-0.07 [-0.50, 0.37]
Melody	0.17 (0.10)	0.14 (0.10)	1.29	85.08	.199	0.28 [-0.15, 0.71]
Timbre	0.29 (0.08)	0.3 (0.09)	-0.59	86.00	.556	-0.13 [-0.55, 0.30]
Rhythm	0.31 (0.09)	0.32 (0.09)	-0.56	85.13	.577	-0.12 [-0.55, 0.30]

Note. Descriptive values show mean ratings for the PANAS (Breyer & Bluemke, 2016), the Big-Five Domains (Rammstedt et al., 2018), and the Gold-MSI (Müllensiefen et al., 2014). AQ score were calculated based on Hoekstra et al. (2008) and Baron-Cohen et al. (2001).

^a *Note that original degrees of freedom were 86 but were corrected due to unequal variance.*

2.4.2 Emotion classification performance

The mean proportion of correct responses was submitted to an ANOVA with Emotion (Happiness, Pleasure, Fear, and Sadness) and Morph Type (Full, F0, and Timbre) as repeated measures factors and Group (singers and instrumentalists) as a between subject factor (see **Table 2**).

The results revealed main effects of **Emotion** and **Morph Type**, which were qualified by an interaction. Crucially, however, we found no main effects or interactions involving **Group** (see **Figure 2**), which was also confirmed by a Bayesian ANOVA (see Table S7 on OSF). Planned Bayesian analysis revealed moderate evidence for the null effect of group for overall performance ($p = .542$, $BF_{10} = 0.265$), as well as for Full ($p = .392$, $BF_{10} = 0.310$), F0 ($p = .935$, $BF_{10} = 0.226$), and Timbre morphs ($p = .555$, $BF_{10} = 0.262$) separately. Thus, we found evidence consistent with our hypotheses H1 and H2.

Table 2

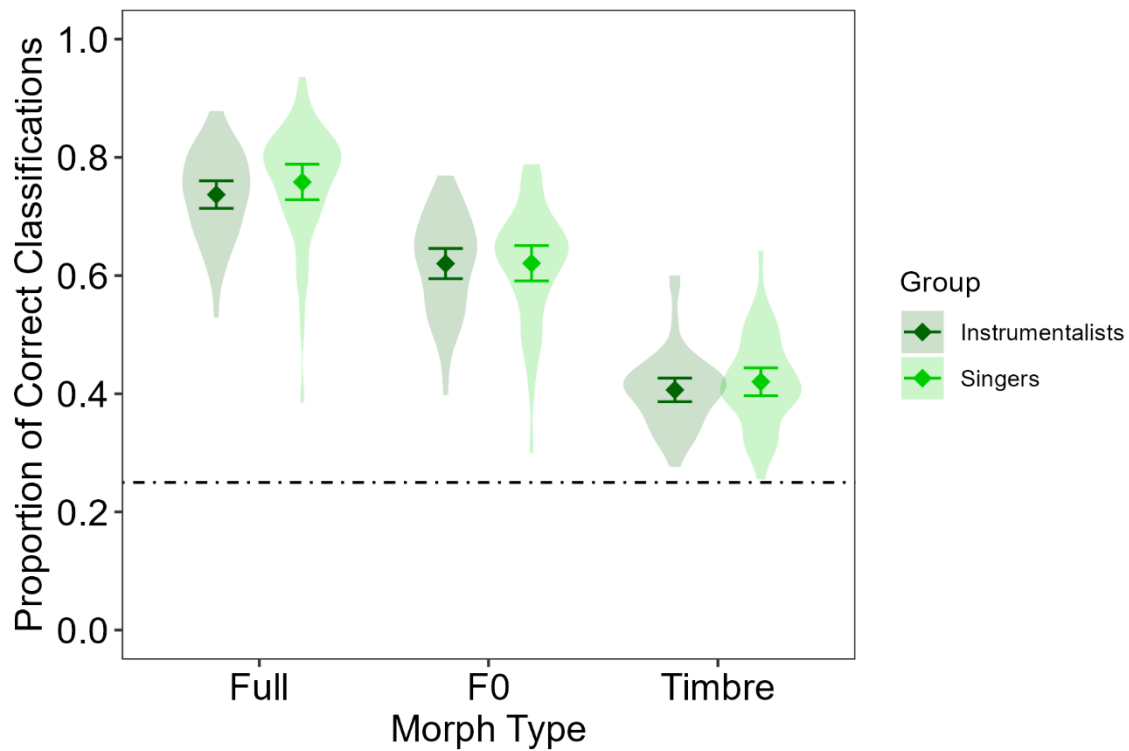
Results of the $4 \times 3 \times 2$ mixed-effects ANOVA on the mean proportion of correct responses

	df1	df2	F	p	Ω_p^2 [95%-CI]	ϵ_{HF}
Group	1	86	0.38	.542	.00 [.00, .01]	
Emotion	3	258	72.43	<.001	.45 [.36, .52]	
Morph Type	2	172	768.93	<.001	.90 [.87, .92]	.741
Group x Emotion	3	258	2.14	.095	.01 [.00, .04]	
Group x Morph Type	2	172	0.36	.635	.00 [.00, .01]	

Emotion x Morph Type	6	516	22.78	<.001	.20 [.14 .25]	.827
Group x Emotion x Morph Type	6	516	1.33	.249	.00 [.00 .01]	

Figure 2

Mean proportion of correct responses per Morph Type separately for singers and instrumentalists



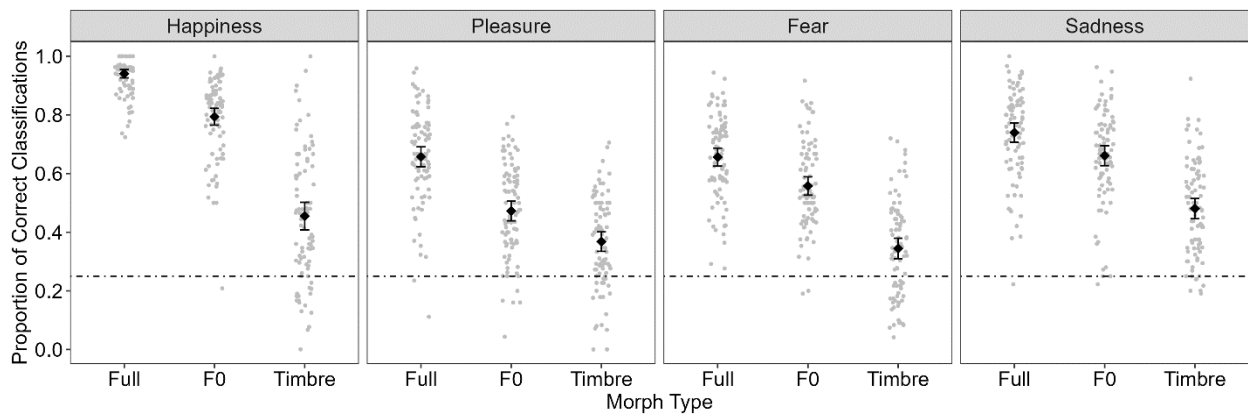
Note. Whiskers represent 95% confidence intervals. Violin plots represent variation of individual participants. The dotted line represents guessing rate at .25.

Follow-up analysis of the Morph Type effect revealed that performance was best in the Full condition ($M = 0.75 \pm 0.01$ SEM), followed by the F0 ($M = 0.62 \pm 0.01$) and then the Timbre condition ($M = 0.41 \pm 0.01$); Full vs. F0: $|t(87)| = 23.28$, $p < .001$, $d = 2.50$ [2.07, 2.92], F0 vs. Timbre: $|t(87)| = 21.44$, $p < .001$, $d = 2.30$ [1.90, 2.70], Full vs. Timbre: $|t(87)| = 33.94$, $p < .001$, $d = 3.64$ [3.06, 4.21]). This Morph Type main effect was also found for all emotions separately (all $F_s(2, 174) > 102.44$, $p < .001$), although it differed slightly between emotions, as suggested by the interaction (see **Figure 3**, for all post-hoc tests, refer to the full analysis

on OSF). Performance difference between F0 and Timbre was largest for Happiness ($M = 0.34 \pm 0.02$ SEM), followed by Fear ($M = 0.21 \pm 0.02$), Sadness ($M = 0.18 \pm 0.02$), and Pleasure ($M = 0.10 \pm 0.02$; all pairwise comparisons $|ts(77)| \geq 2.57$, $ps \leq .012$, $ds \geq 0.28$ [0.06 0.49], except for Fear vs. Sadness ($|t(87)| = 1.13$, $p = .261$). These effects of Morph Type and Emotion therefore present a full replication of the patterns reported in Nussbaum et al. (2024). For confusion matrices and supplemental analyses, please refer to Figures S1-S3 on OSF.

Figure 3

Mean proportion of correct responses per Emotion and Morph Type



Note. Whiskers represent 95%-confidence intervals. Grey dots represent individual participants' data. The dotted line represents guessing rate at .25.

3 Part II: Correlational analyses

3.1 Hypotheses

In Part II, we focused on the correlations between auditory sensitivity and vocal emotion recognition. We aimed to replicate the patterns found in Nussbaum et al. (2024), and therefore formulated the following hypotheses:

Correlations with the PROMS

H3: Averaged vocal emotion recognition (VER) performance is correlated with averaged music perception performance.

H4: Full-VER and F0-VER are correlated with melody perception in music

Correlations with the GOLD-MSI:

H5: Averaged-VER and Full-VER are correlated with the General-ME.

H6: Averaged-VER and Full-VER are correlated with the Perception Subscale

H7: Averaged-VER and Full-VER are correlated with self-rated singing abilities.

3.2 Data analysis

We calculated Spearman correlations between vocal emotion perception performance and both the PROMS music perception performance and the Gold-MSI self-rated musicality. P-values were adjusted for multiple comparisons using the Benjamini-Hochberg correction (Benjamini & Hochberg, 1995). Following our pre-registered plan, all correlations were controlled for formal musical education as well, but we found that this made no difference to the observed patterns.

3.3 Results

Replicating our previous findings, we obtained a strong correlation between vocal emotion recognition and music perception performance, as measured with the PROMS (Table 3, and Table S10 on OSF). Further, we replicated the specific link between vocal emotion perception and the melody subtest. Although we did not have a specific hypothesis, we again found a link with Rhythm perception. There were no links between performance in the timbre morph condition and the timbre subtest. Overall, this pattern of correlations almost completely replicates the pattern observed in a previous sample (Nussbaum et al. 2024, Table 2, page 12). Thus, the link between auditory sensitivity and vocal emotion perception seems to be highly comparable across professional musicians, non-musicians and amateurs.

Table 3

	PROMSAvg	Pitch	Melody	Timbre	Rhythm
VERAvg	.39 (.002)	.17 (.142)	.29 (.017)	.23 (.050)	.38 (.002)
Full-Morphs	.34 (.005)	.14 (.219)	.27 (.022)	.23 (.050)	.31 (.009)
F0-Morphs	.39 (.002)	.16 (.186)	.34 (.005)	.24 (.044)	.32 (.008)
Timbre-Morphs	.22 (.054)	.12 (.305)	.08 (.473)	.10 (.352)	.25 (.039)

Note. VER = Vocal Emotion Recognition performance. p-values were adjusted for multiple comparisons using the Benjamini-Hochberg correction (Benjamini & Hochberg, 1995)

In contrast, we found no links between vocal emotion recognition performance and self-rated musicality, as measured by the Gold-MSI (all correlations ≤ 0.21 , $ps \geq .051$, both with and without correction for formal musical education, details on Tables S11 and S12 on OSF). Thus, for amateurs, we could not replicate the link with self-rated musical sophistication, perception and singing abilities, which we observed in our previous sample of professional musicians and non-musicians. Therefore, we found evidence for our hypotheses H3 and H4, but not for hypotheses H5 – H7.

4 Part III: Comparison of professionals, amateurs and non-musicians

In the third part, we compared amateur musicians to both professional musicians and non-musicians. We predicted that amateurs and professional musicians would be comparable regarding vocal emotion perception. However, as the evidence reviewed above showed that amateurs can differ from professionals in cognitive abilities which could be linked to emotional sensitivity, we also considered the option that amateurs could be more proficient at making emotional inferences than professionals. Compared to our group of non-musicians, we assumed that amateurs would outperform them when emotions were expressed via full

emotion cues and F0 cues only, but not timbre, because this is exactly the pattern we observed for the comparison of professional musicians and non-musicians in Nussbaum et al. (2024).

4.1 Hypotheses

H8: Amateur musicians outperform non-musicians in vocal emotion perception, in the Full and in the F0 condition.

H9: Amateurs perform equal or better to professional musicians in the Full and the F0 condition.

4.2 Method

For this analysis, we collapsed all participants from Part I into the group of amateur musicians and compared it to the groups of professional musicians and non-musicians reported in Nussbaum et al. (2024). Note that we added one participant to the professional group, because he held a master's degree in music (see Part I), so numbers slightly diverge from the original publication. All professional musicians reported to have a music-related academic degree or a non-academic music qualification. Non-musicians played no instrument or engaged in any other musical activities. For a more detailed description, please refer to Nussbaum et al. (2024).

In total, we analyzed data from 40 professional musicians (20 male, 20 female, aged 20 to 42 years [$M = 29.6$; $SD = 5.58$]), 38 non-musicians (18 male, 20 female, aged 19 to 48 years [$M = 30.5$; $SD = 6.54$]) and 88 amateurs (40 male, 46 female, 2 diverse, aged 18 to 54 years [$M = 27.8$; $SD = 9.44$]).

The stimulus material, design and data analysis were identical to Part I. We focused our analysis on the comparison of amateurs with the other two groups, because the comparison of professional musicians and non-musicians is reported in Nussbaum et al. (2024).

4.3 Results

4.3.1 Demography, musicality, and personality of participants

Professionals, amateurs and non-musicians did not differ in the socioeconomic status assessed via educational level ($\chi^2(6, N = 166) = 11.11, p = .085$) and highest academic degree ($\chi^2(16, N = 166) = 24.04, p = .089$). However, there were differences regarding household income ($\chi^2(8, N = 166) = 20.19, p = .010$, Cramer's $V = .25$), with amateurs reporting higher household income than professionals and non-musicians.

Participant characteristics are summarized in **Table 4**. For a full report of statistical details, please refer to Tables S13-S21 on OSF. The groups were comparable in age as well as in positive and negative affect (assessed with the PANAS). For the Big Five, analyses of variance revealed group differences for extraversion, with slightly higher levels in professionals than in amateurs. Regarding autistic traits, the three groups did not differ in their overall score, but there were differences on several subscales. In the Gold-MSI, professional musicians scored significantly higher than amateurs on all subscales, which in turn scored higher than non-musicians. This is a pattern (professionals > amateurs > non-musicians) one would expect for self-rated musicality. In the PROMS, professionals outperformed amateurs in the Pitch and Melody subtest, whereas there were no differences in the Timbre and Rhythm subtests. Amateurs performed better than non-musicians in the Pitch, Melody and Rhythm subtest but not in the Timbre subtest. Thus, a clear pattern of professionals > amateurs > non-musicians was only found for melody and pitch.

Table 4*Characteristics of participants - Demography, personality, and musicality*

	Professionals		Amateurs		Non-Musicians
	M (SD)		M (SD)		M (SD)
<i>PANAS</i>					
positive Affect	3.32 (0.65)		3.05 (0.63)		3.1 (0.67)
negative Affect	1.69 (0.48)		1.47 (0.42)		1.49 (0.69)
<i>Big Five</i>					
Openness	4.12 (0.50)		4.02 (0.53)		3.81 (0.80)
Conscientiousness	3.49 (0.71)		3.61 (0.70)		3.76 (0.72)
Extraversion	3.48 (0.66)	>	3.11 (0.72)		3.38 (0.79)
Agreeableness	3.92 (0.57)		3.91 (0.59)		3.75 (0.66)
Neuroticism	2.95 (0.65)		2.69 (0.77)		2.58 (0.82)
<i>AQ</i>					
Total	15.7 (4.98)		18.73 (7.40)		17.58 (6.41)
Attention to Detail	5.43 (2.04)		5.51 (2.42)	>	4.32 (2.01)
Social	10.28 (4.70)	<	13.22 (6.49)		13.26 (6.51)
Social Skills	1.48 (1.68)	<	2.74 (2.49)		2.61 (2.63)
Communication	1.85 (1.61)		2.49 (2.12)		2.39 (1.73)
Imagination	2.18 (1.52)		2.66 (1.81)		2.87 (1.95)
Attention Switching	4.78 (1.91)		5.33 (2.06)		5.39 (1.92)
<i>Gold-MSI</i>					
General ME	5.68 (0.50)	>	4.76 (0.82)	>	2.74 (1.07)
Active Engagement	4.94 (0.81)	>	4.02 (1.00)	>	2.95 (1.19)
Formal Education	5.95 (0.56)	>	4.66 (0.96)	>	1.71 (0.68)
Emotion	5.88 (0.73)	>	5.55 (0.78)	>	4.95 (1.32)
Singing	5.34 (0.83)	>	4.59 (1.19)	>	2.84 (1.26)
Perception	6.31 (0.51)	>	5.75 (0.92)	>	4.22 (1.49)
<i>PROMS</i>					
Pitch	0.27 (0.06)	>	0.24 (0.07)	>	0.18 (0.06)
Melody	0.23 (0.08)	>	0.16 (0.10)	>	0.07 (0.08)
Timbre	0.32 (0.08)		0.29 (0.08)		0.26 (0.09)
Rhythm	0.33 (0.08)		0.32 (0.09)	>	0.27 (0.08)

Note. Descriptive values show mean ratings for the PANAS (Breyer & Bluemke, 2016), the

Big-Five Domains (Rammstedt et al., 2018), and the Gold-MSI (Müllensiefen et al., 2014).

AQ score were calculated based on Hoekstra et al. (2008) and Baron-Cohen et al. (2001).

Comparison signs (“>” or “<”) indicate significant differences. For a full report of statistical details, please refer to OSF.

4.3.2 Emotion classification performance

The mean proportion of correct responses was submitted to an ANOVA with Emotion (Happiness, Pleasure, Fear, and Sadness) and Morph Type (Full, F0, and Timbre) as repeated measures factors and Group (professionals, amateurs, and non-musicians) as a between subjects-factor (see **Table 5**). For the parallel Bayesian ANOVA, please refer to S8 on OSF.

The results revealed the main effects of **Emotion** and **Morph Type**, which were qualified by an interaction. Crucially, however, we found no main effect involving **Group** and only a trend for an interaction between **Group and Morph Type**.

Table 5

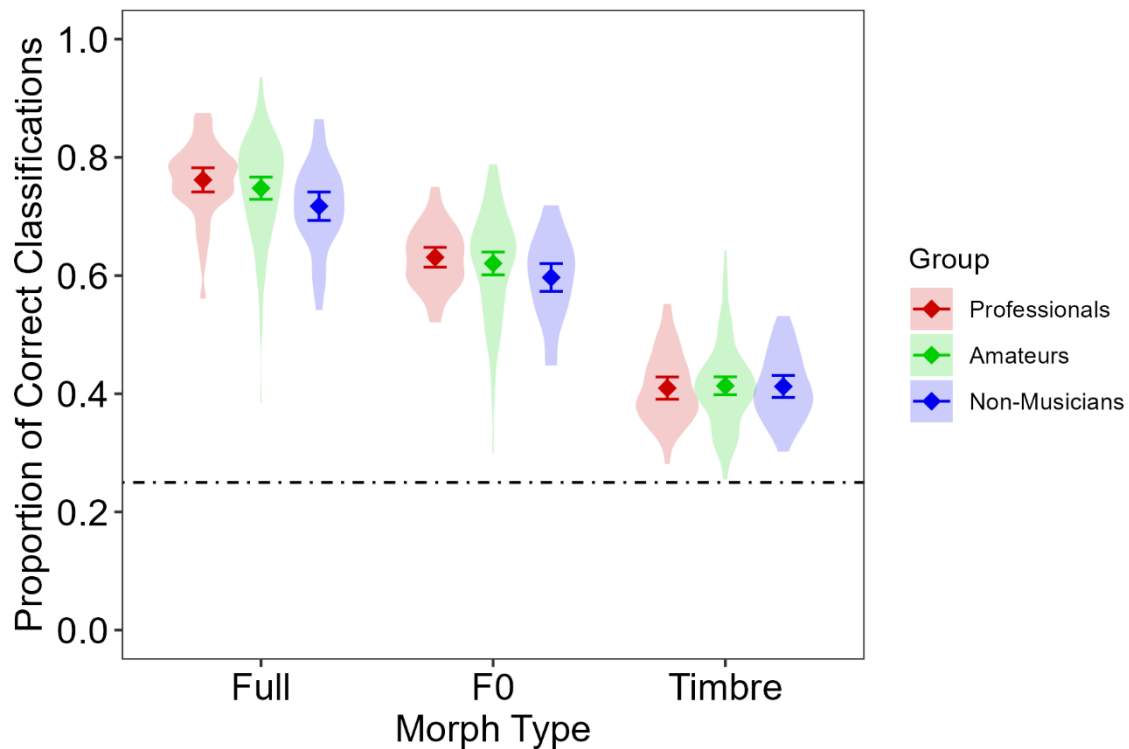
Results of the $4 \times 3 \times 3$ mixed-effects ANOVA on the mean proportion of correct responses

	df1	df2	F	p	Ω_p^2 [95%-CI]	ϵ_{HF}
Group	2	163	1.96	.144	.01 [.00, .06]	
Emotion	3	489	130.24	<.001	.44 [.38, .49]	
Morph Type	2	326	1357.80	<.001	.89 [.87, .91]	.829
Group x Emotion	6	489	1.17	.322	.00 [.00, .01]	
Group x Morph Type	4	326	2.14	.089	.01 [.00, .04]	.829
Emotion x Morph Type	6	978	40.95	<.001	.20 [.15, .24]	.875
Group x Emotion x Morph Type	12	978	0.74	.688	.00 [.00, .01]	.865

Planned comparisons between **professionals and amateurs** revealed moderate evidence for the null effect of overall performance ($p = .473$, $BF_{10} = 0.238$), as well as for Full ($p = .322$, $BF_{10} = 0.286$), F0 ($p = .435$, $BF_{10} = .245$), and Timbre morphs ($p = .840$, $BF_{10} = 0.205$) separately. Planned comparisons between amateurs and non-musicians revealed inconclusive evidence for overall performance ($p = .107$, $BF_{10} = 0.546$), as well as for Full ($p = .044$, $BF_{10} = 1.009$), and F0 ($p = .105$, $BF_{10} = 0.576$) separately. For Timbre morphs, there was moderate evidence for the null effect ($p = .975$, $BF_{10} = 0.205$). Thus, we found evidence consistent with H9, but inconclusive evidence regarding H8.

Figure 4

Mean proportion of correct responses per Morph Type separately for professionals, amateurs, and non-musicians



Note. Whiskers represent 95% confidence intervals. Violin plots represent variation of individual participants. The dotted line represents guessing rate at .25.

5 Discussion

In the present study, we shed new light on the link between musicality and vocal emotion perception, by focusing on different subgroups of musicians. In line with our hypotheses, emotion recognition was found to be comparable between both singers and instrumentalists, and also between amateur musicians and professionals. We further replicated the consistent link between sensitivity towards musical patterns and vocal emotion perception, although this was reflected in objective performance measures only, but not in self-rated musicality. In total, these results suggest that the link between musicality and vocal emotion perception is

driven by individual differences in auditory sensitivity, which is not tied to a particular type or amount of musical activity. In what follows, we will discuss these findings in more detail.

5.1 Singers vs. instrumentalists

For the present study, we recruited a well-powered sample of singers and instrumentalists, which were comparable with regard to personality, socio-economic background, and objective music perception performance. They only differed in two aspects of self-rated musicality: unsurprisingly, singers scored higher on self-rated singing abilities, and instrumentalists scored higher on self-rated formal education. The latter may be because mastering an instrument to the point where one can play in an ensemble arguably takes more formal training than being able to sing in a choir.

In line with our prediction, the vocal emotion recognition performance of singers and instrumentalists did not differ in any condition, as supported by Bayesian analysis with moderate evidence. This finding does not simply represent a general absence of effects. In fact, we replicated the strong and consistent effect of vocal parameters (manipulated via voice morphing) on emotion recognition, with F0 contour being relatively more informative than timbre, across all emotions, while performance was still best in the Full condition. The fact that this pattern was found to be highly comparable for singers and instrumentalists suggests that they use the same acoustic cues to perceive vocal emotions and do so with comparable efficiency.

Although this is precisely what we predicted, we want to address two observations from the literature which may seem incompatible with our findings: First, our findings diverge from Thompson et al. (2004), who found that singing lessons may interfere with vocal emotional processing. However, this study had several methodological limitations including a very small sample size and large drop-out rates. With the present, substantially powered design, we do not see any evidence for a disruptive effect of active singing. This aligns with

the broader literature on protective effects of singing on cognitive and socio-emotional functioning (Moisseinen et al., 2024; Tragantzopoulou & Giannouli, 2025). Second, several studies found correlations between singing abilities and emotion recognition (Correia et al., 2022; Greenspon & Montanaro, 2023; Nussbaum et al., 2024). However, all these studies included both singers and instrumentalists. In fact, it is quite common that instrumentalists have good singing abilities as well, although it is not their preferred form of musical expression. Thus, while we do not argue against a relationship between singing abilities and emotion recognition per se, we lack evidence that emotion recognition is more pronounced in specific groups of musicians, or that this is causally linked to certain musical activities. Instead, this correlation seems to be mediated via natural auditory sensitivity. Note that we failed to find the predicted correlation between self-rated singing abilities and emotion recognition in the present study. This may be attributed to potentially decreased variance in our group of amateurs with regard to self-rated musicality (Gold-MSI). In fact, we did not find any correlations with the Gold-MSI subscales in amateurs, which is in contrast to the pattern we had observed in the sample comprised of professionals and non-musicians (Nussbaum et al., 2024).

5.2 Amateurs compared to professional musicians and non-musicians

As predicted, we found evidence that emotion perception performance does not differ between amateur musicians and professionals, further strengthening the notion that the amount of music training is not a major influence on vocal emotion perception (Schellenberg & Lima, 2024). We also had hypothesized that amateurs would outperform non-musicians, because professionals outperformed them in our previous study (Nussbaum et al., 2024). This comparison yielded inconclusive evidence. We speculate that the present amateur sample was more heterogenous than the professional one, and as a result, our design may have lacked

statistical power to detect potentially small differences between amateurs and non-musicians, despite the substantial sample size. This issue may be resolved in a follow-up study.

In addition to the direct group comparison, we performed a correlational analysis on our sample of amateurs (Part II) which was in parallel to an analysis we had performed previously on professionals and non-musicians (cf. Table 2 and Table 3 in Nussbaum et al., 2024). Importantly, we found a highly similar pattern of correlations between vocal emotion perception and music perception abilities, especially for melody and rhythm. We therefore conclude that individual differences in music perception abilities play an important role, irrespective of the assignment to any (non)-musical group. This is fully in line with the current literature, which consistently emphasizes the role of auditory sensitivity and argues against a causal effect of training or musical activity on vocal emotion perception (Neves et al., 2025; Schellenberg & Lima, 2024).

5.3 Directions for future directions

To the best of our knowledge, this study is the first substantially powered comparison between different subgroups of musicians with respect to vocal emotion recognition and therefore closes an open gap in the literature. Nevertheless, the present study has several limitations which deserve consideration. All musicians were socialized in Western music culture and fluent German speakers, therefore findings may not generalize to other music and language backgrounds (Morrison & Demorest, 2009). Note, however, that links between music perception performance and emotion recognition irrespective of formal musical training have been observed in a Portuguese sample as well (Correia et al., 2022).

What posed a particular challenge in the present study was the recruitment of mutually exclusive groups of musicians. While the distinction between singers and instrumentalists may seem trivial at first glance, it is actually rare that musicians engage in one of these activities only. Thus, for practical reasons, we recruited participants who self-assigned clearly

to one form and made sure that their current activity is either one or the other. Yet, some of the singers reported that they used to play an instrument as well. In a similar vein, the distinction between amateurs and professionals is not fully straightforward and may represent a continuum rather than clear-cut categories. Some individuals pursue music as a profession, but without a formal music degree, others vice versa (Zendel & Alexander, 2020). Some people transition from amateurs to a professional level later in life (Taylor & Hallam, 2011). Thus, while the argument still holds that future research should incorporate the heterogeneity of musicians, it may be more adequate to pursue variability on a spectrum rather than for distinct groups.

While the present behavioral data did not reveal differences between musical subgroups, future research may unravel more fine-grained patterns in the brain. Several studies have reported brain differences in auditory and motor processing between amateurs and professionals (Kleber et al., 2010; Lotze et al., 2003; Oechslin et al., 2013; Papadaki et al., 2023) and singers and instrumentalists (Halwani et al., 2011), but as yet such studies do not provide insights into vocal emotional processing. While we observed differences in electrophysiological responses in professional musicians and non-musicians during vocal emotion recognition (Lehnen et al., 2025; Nussbaum et al., 2023), a meaningful fine-grained comparison between singers and instrumentalists, or amateurs and professionals, would arguably require a much bigger sample.

Finally, with respect to the individual dynamics of the tight neural overlap of expression and perception in vocal communication, we hold that it may be worthwhile to focus on another group of vocal experts: professional voice actors or imitators. This is because such experts, unlike singers, are specifically trained to express emotions in the *spoken* voice. In fact, a recent study found that voice actors show enhanced sensitivity for linguistic voice prosody and enhanced neural tracking for voice pitch compared to non-actors (Kachlicka &

Tierney, 2024). Vocal acting usually involves deliberate exaggeration of vocal expressions and may therefore require a fine-grained explicit representation of vocal emotions (Berry & Brown, 2019). While there is research comparing actors and non-actors regarding the expression of emotions (Jürgens et al., 2015), we do not know how this is mirrored in vocal emotion perception performance and how this group may differ from individuals with singing expertise.

6 Summary and Conclusion

In the present study, we investigated how emotion perception differs in musical subgroups and compared singers and instrumentalists as well as amateurs and professionals. In line with our prediction, we observed no differences between musical subgroups, suggesting that emotion perception abilities are not primarily tied to the type or amount of musical activity. Instead, we replicated the link between vocal emotion perception and music perception abilities, especially for melodies. This adds a new perspective to the accumulating evidence that the link between musicality and vocal emotion perception is predominantly driven by individual differences in natural auditory sensitivity.

7 Acknowledgements

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8 Conflicts of Interests

The authors declare no competing interests.

9 Declaration of generative AI and AI-assisted technologies in the writing process

No generative AI or AI-assisted technologies were used in the writing process of this manuscript.

10 Credit Author Statement

Christine Nussbaum – Conceptualization, Methodology, Software, Visualization, Formal analysis, Writing - Original Draft, Supervision

Jessica Dethloff - Data collection, Formal analysis, Visualization, Writing - Original Draft

Annett Schirmer – Methodology, Writing - Review & Editing, Supervision

Stefan R. Schweinberger – Conceptualization, Writing - Review & Editing, Supervision

11 Resource availability

Requests for further information and resources should be directed to and will be fulfilled by the lead contact, Christine Nussbaum (christine.nussbaum@uni-jena.de).

Data: All raw and preprocessed data have been deposited at the associated OSF repository (<https://osf.io/ascqx/>) and are publicly available.

Code: All original code for data analysis has been deposited at the associated OSF repository (<https://osf.io/ascqx/>) and is publicly available.

Additional information: Supplemental figures and tables have been deposited at the associated OSF repository (<https://osf.io/ascqx/>) and are publicly available.

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